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THE CANADIAN FISH CULTURIST

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Published under Authority

of

HON. H.J. ROBICHAUD, M.P.

Minister of Fisheries

Progress in Canadian Oyster Hatchery Development

by

R. E. Drinnan[1] *and* J. P. Parkinson[2]

A supply of seed oysters is the most pressing need of the oyster industry of the Maritime Provinces. Natural oyster production is extremely variable and steadily decreasing in the face of the deleterious changes in our bays and estuaries brought about by man's activities. Attempts to utilize natural seed oyster production as efficiently as possible are continuing, but even at best the supply from this source is too small and too unreliable to support a healthy industry.

The concept of utilizing the tremendous reproductive potential of the oyster to produce large quantities of seed under controlled conditions is not a new one. Much of the basic information required to make this a reality has been available for some years, but little practical progress has been made in converting this knowledge into a reliable industrial process. Using this knowledge as a springboard, rearing of oyster larvae at Ellerslie began on a laboratory scale in 1959. The results were sufficiently encouraging to justify the building of facilities to test the technique on a commercial scale.

Working with the basic concepts provided by Fisheries Research Board of Canada scientists, the Fish Culture Development Branch engineers designed, and had constructed in 1963, the Experimental Oyster Hatchery at Ellerslie, Prince Edward Island. It was officially opened by the Minister of Fisheries in 1964 and has operated from the beginning under Board supervision with staff from both the Department and the Board.

Aims

The aims of the Experimental Oyster Hatchery program are twofold.

The first is to develop reliable techniques of rearing seed oysters on a commercial scale. When this is accomplished, it is expected that private commercial oyster hatcheries will evolve to fulfil the seed requirements of oyster farmers. The experimental hatchery would have a continuing role to play in further development and refinement of techniques, training of personnel, providing technical advice, and carrying out some of the technically more difficult operations as a service to industry. The details of this relationship can only be determined when the techniques and their relative cost and technical difficulty are determined.

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The second is to select stocks of oysters with desirable characteristics, such as fast growth and disease resistance. It is known that there are differences in resistance to disease between natural stocks of oysters and there is evidence that such stocks differ in other ways also. The feasibility of using such selected stocks will depend on the availability of a method of breeding them in sufficient quantities to supply industry. Breeding from selected fast-growing oysters has already begun in the hatchery as the first step towards developing a strain which will grow faster than those now available.

Hatchery Layout and Staff

Oysters reproduce by releasing eggs and sperms. One female may emit in excess of 20 million microscopic eggs. The fertilized eggs develop into free swimming larvae which subsequently settle and metamorphose into small oysters known as spat.

The hatchery is designed to provide facilities for the steps involved in producing oyster spat for growth outside. These steps are: conditioning of the gonads, spawning, larval rearing, spat settlement, and spat rearing.

The hatchery was designed to provide separate areas for these steps and for ancillary facilities for food culture for the spat and larvae. The mechanical equipment, including pumps, temperature control equipment, sea water filters, and clarifier, is contained in a room at one end of the building. Processed water is then piped to the appropriate areas elsewhere in the building. In addition, the hatchery contains an office for records and a small laboratory.

Experience at Ellerslie has shown that a staff of four technicians will be required for the operation of the oyster hatchery. In addition to this, it has been necessary to utilize casual labour for short periods. It is likely, with suitable automation of the larval rearing operation, that a large commercial oyster hatchery would operate with the same staff.

Water Supply

Water is drawn continuously from the estuary through a polyethylene pipe by self-priming pumps. The system is designed to cope with two natural hazards, damage by storms and winter ice and internal fouling of the intakes by marine organisms. The fouling organisms cut down water flow and also act as a very efficient filter, removing the natural food of the oyster larva.

There are actually three intakes, one for use during the winter periods, when there is no marine fouling, and two smaller summer lines. In the winter line, the polyethylene pipe is placed inside an asbestos-cement pipe which doubles as a drain for waste water. This arrangement is very satisfactory as it permits changing the intake line simply by withdrawing it and inserting a new line from inside the hatchery. Two people can replace 250 feet of line in about half an hour. The line runs underground from the building to below low water level and continues underwater below the level reached by winter ice which averages 3 feet in thickness at Ellerslie. The summer lines are similarly arranged except that they are inside large polyethylene pipes which do not serve as drains.

These lines are shorter and of smaller diameter and are used alternately during the summer period when marine fouling occurs. The intake end of the line not in use is raised above the surface and the line is filled with fresh water to kill any accumulated fouling organisms. These dead organisms are flushed out before the line is placed back in service.

The accumulation of silt and fouling in the intakes is an important factor in the hatchery process. Therefore, the intake lines are the minimum length necessary to obtain a suitable water supply.

Water Clarification

It is essential that all water entering the hatchery system be clarified. Animals which would settle in the hatchery and compete with oysters for food, and silt which would foul the system and interfere with oyster raising must be removed. In addition, the efficiency of water sterilization by ultra-violet light, a later step in water treatment, is greatly increased by efficient clarification of the sea water. At the same time, the small plants used as food by oyster larvae and spat should not be removed.

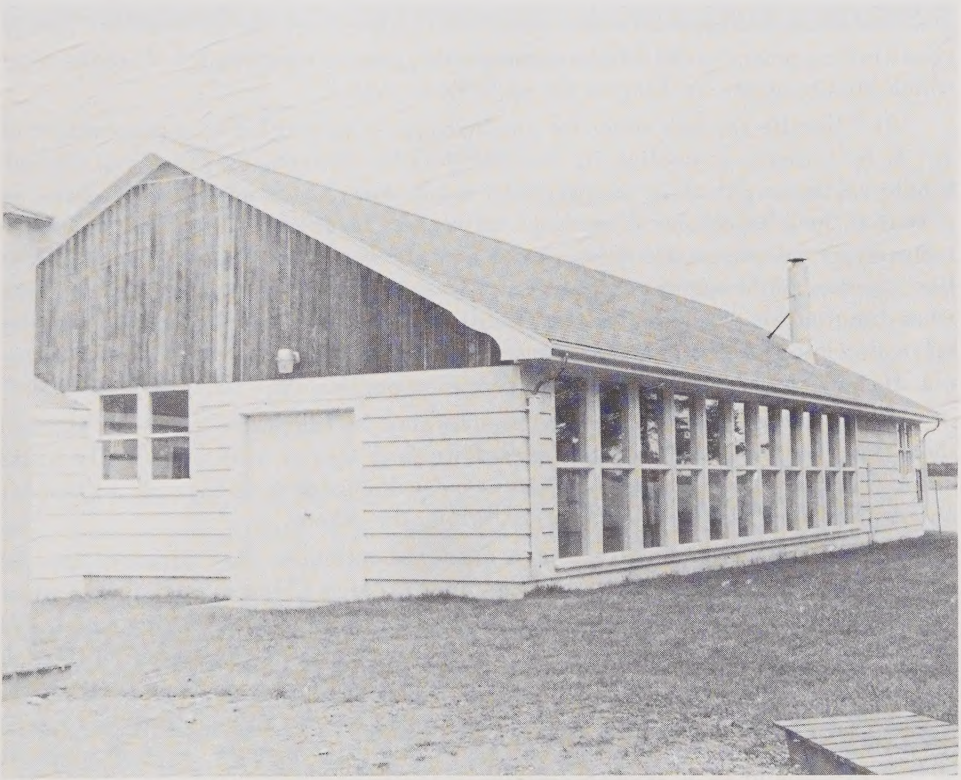

Figure 1. The Experimental Hatchery building from the south side.

Initially this clarification was accomplished by passing the water through cartridge-type filters. Later, upon the completion of laboratory testing, a large, centrifugal clarifier was installed. Both of these devices are satisfactory, but each has certain disadvantages. The filters provide water of suitable quality without removing the useful food organisms, but, when there is a heavy silt load, the cartridges must be changed frequently, with resultant increased operating costs. The centrifugal clarifier is extremely efficient with respect to providing clean sea water. To avoid removing all useful food organisms, the machine must be operated above its rated capacity. The main disadvantages of this equipment are: that it is too costly for a commercial hatchery to install and operate, that it must be operated at a fixed, highflow rate, and that the stainless steel in the bowl is subject to electrolytic corrosion. Metallic ions thus released have adverse effects on the oyster eggs and larvae.

Other methods of water clarification, including the use of sand filters, are being considered and tested.

Conditioning of Parent Stocks for Spawning

In natural conditions oysters develop ripe gonads in early summer and spawn when water temperatures reach suitable levels. In the hatchery, spawning must be controlled to supply fertilized eggs as required. This is readily achieved by holding the adults in sea water at a temperature of 18°C (64°F) for the conditioning process. At this temperature the gonads ripen in 3 – 4 weeks after which spawning can be delayed for up to two months.

At Ellerslie the sea water for conditioning is controlled to a temperature of 18° C by warming or cooling it, depending on the season, by passing it through a heat exchanger. Heat is supplied from a hot water boiler which also serves as a heating unit for the building. Cool well water is used to lower the sea water temperature. A pneumatic temperature control system is used because of the fine degree of temperature modulation possible. A major problem developed when electrolytic corrosion of the stainless steel tubes in the heat exchangers released metallic ions to the sea water in the same way as with the centrifugal clarifier. Means of overcoming these corrosion problems are being investigated.

The oysters are conditioned for spawning in fibreglass trays so stacked that water introduced at the top runs down from tray to tray and finally to the drain. This is a convenient and compact unit which makes it possible to inspect any desired tray of oysters without disturbing the others.

Experience now indicates that a smaller continuous flow of water may be used in this step. This water would be stored in large fibreglass reinforced plastic (FRP) tanks. The stainless-steel heat exchanger would be eliminated and the water temperature controlled by passing hot or cold water as required through coils built into the tank, or by the use of inert immersion type heat exchangers. The heat-sink effect of this quantity of water would give extremely uniform temperatures. The water would then be circulated through the trays of oysters, or the trays could be supported directly in the tank. This revision in the conditioning process is being tested at Ellerslie.

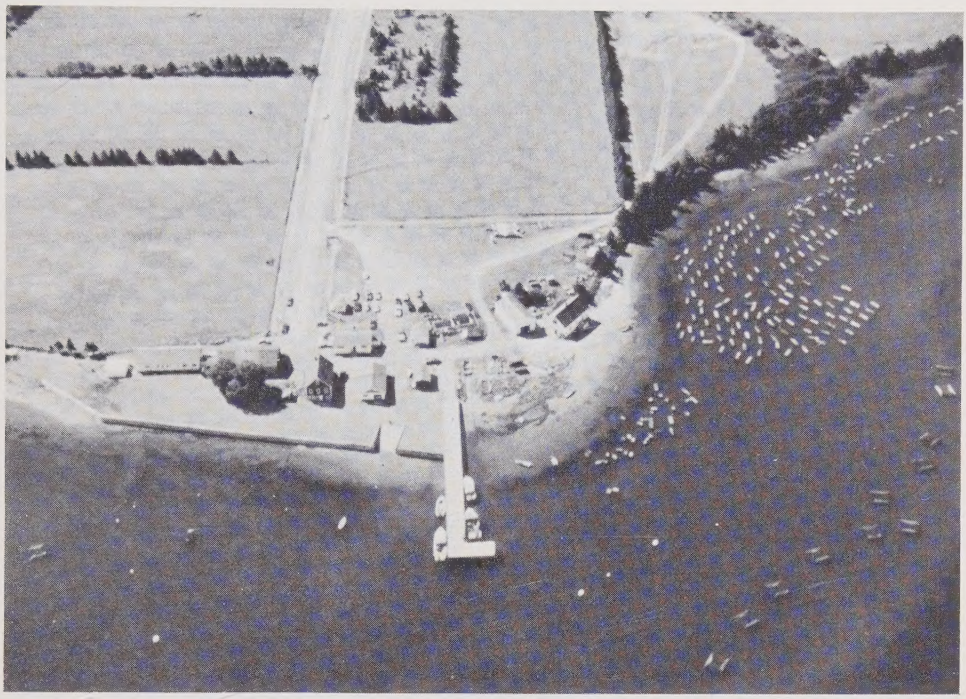

Figure 2. Aerial view of Ellerslie Oyster Hatchery.

Spawning

To stimulate spawning, ripe oysters from the conditioning trays are placed in clean sea water and the temperature is raised to 25–30°C (77–86°F). Oysters which spawn are removed to containers of clean sea water. Eggs released are washed through a fine screen, sperm added and the fertilized eggs put into rearing containers. If oysters are fully ripe, the whole spawning process is a rapid and simple one. Within twenty-four hours the fertilized eggs develop into swimming larvae.

Larval Rearing

The larval stage is the most vulnerable phase of the oyster's life, and this step is the most difficult in the hatchery process. Water quality is of supreme importance here.

Larvae are reared in conical FRP tanks each containing 100 gallons of sea water and 3 – 5 million larvae. Clarified sea water at 20°C is supplied to the tanks via an ultra-violet sterilizer where bacteria in the water are killed. Control of bacteria in larval cultures is essential to successful larval culture. The initial installation used a fixed sterilizer from which sterilized sea water was distributed to the rearing tanks. This system involves the danger of recontamination of the sea water by bacteria which multiply in the distribution system. It is important that this distribution system be as short as possible and be

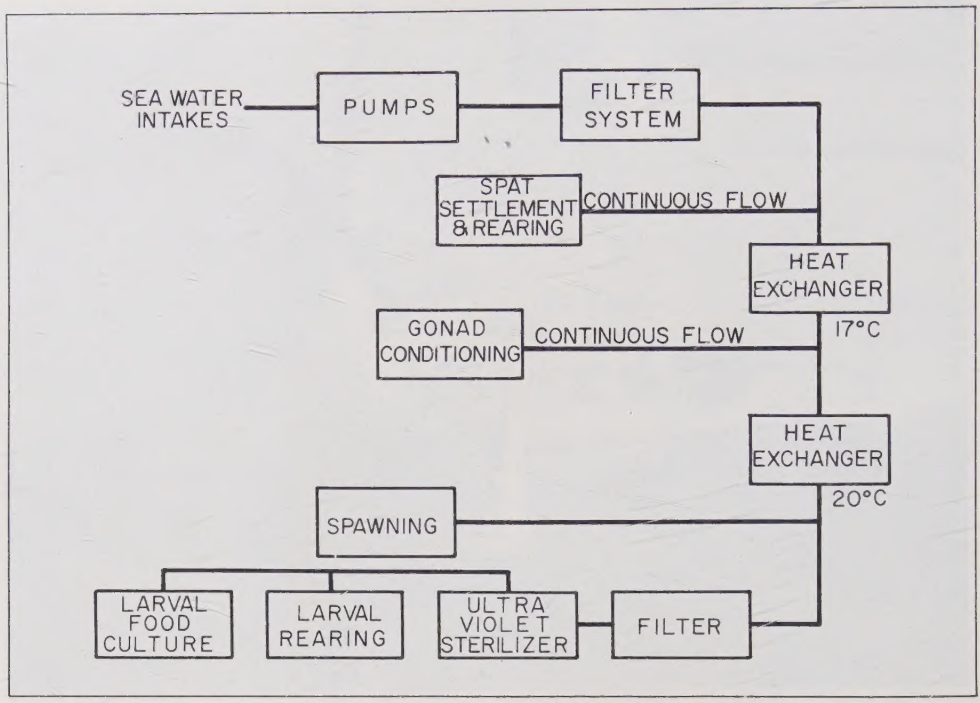

Figure 3. Schematic showing water treatment and distribution in the Hatchery.

cleaned out regularly. Two alternative techniques are being tested, sterilization of the water directly in the tank and a mobile sterilization unit which delivers sterile water directly to the rearing tanks.

Antibiotics have been widely used to control bacteria in rearing larvae. In early trials at Ellerslie, they were used routinely. Bacteria are now controlled by regular water changes and in-plant hygiene with the antibiotics held in reserve for emergencies.

Oyster larvae are held in the rearing tanks until they reach setting size. This usually takes 19 – 21 days at a temperature of 20°C (68°F). During this time the water is changed daily. The contents of the tanks are run off through a nylon screen of a suitable size to retain the larvae, which are washed thoroughly and returned to the tank, which has been cleaned and refilled with new sterilized sea water.

Experience at Ellerslie in the past six years has shown that the local waters are normally sufficiently rich in natural food during the open water period to sustain larval growth. Supplementary cultured foods must be added only during the winter or unusually poor years.

The history of larval rearing in the hatchery has been a mixed one. In earlier laboratory studies no difficulties had been encountered providing larvae were given sufficient food. After an initial successful rearing, early attempts in

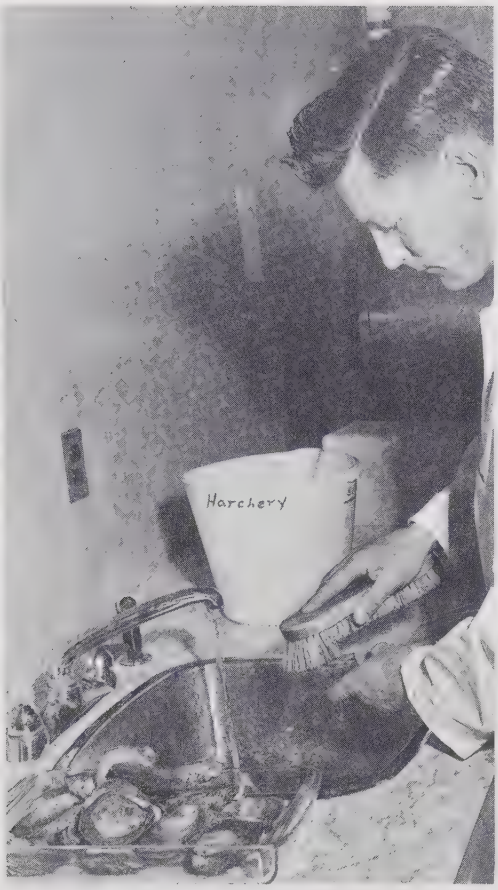

Figure 4. Parent oysters are carefully cleaned before introduction to the Hatchery.

the experimental hatchery failed completely. Eggs often failed to develop properly and larvae did not grow. These results were eventually traced to toxic materials released by electrolytic corrosion of stainless steel in the heat exchangers. Sacrificial, magnesium-zinc electrodes connected to all stainless steel equipment immersed in sea water running to waste removed the biological effects, though some corrosion still takes place.

In general, since this corrosion was reduced, larval rearing has been very successful, with the larvae growing and surviving well. Low growth rates and high mortalities did occur in some larval batches in the summer of 1965. These were traced to either poor feeding conditions due to fouling of the intake lines or high bacterial counts in the rearing tanks from dirty distribution lines. Improved maintenance and strict sanitation removed the sources of these difficulties. The larval rearing step, though basically quite simple, consumes the largest portion of the staff's time. For this reason, it is the step which should receive the closest attention with respect to automating the oyster hatchery operation.

Figure 5. Oysters are held in warm sea water (17-18•C) for three to four weeks to induce ripening of gonads.

Figure 6. Spawning is triggered by raising the sea water temperature.

Spat Setting

When larvae reach setting size, they are screened out on a nylon mesh of appropriate size and transferred to tanks provided with suitable collector materials.

The requirements of a collector material are complex. A suitable collector must be non-toxic and attractive to oyster larvae. It must be compact enough to allow sufficient water circulation to achieve good growth. It must be robust enough to withstand handling but also allow the separation of individual oysters when these have grown large enough. A number of materials have been tested. The one currently showing the most promise is a wood-veneer ring coated with a sand-cement mixture, then leached for a week in sea water to remove toxic elements. Another which shows great promise is a polyvinyl-chloride mesh which is now in commercial use in France. The mesh is coated with a sand-lime mixture and has the advantage that, after removal of the oysters, the basic material can be re-used.

Originally, setting was carried out in large polyethylene tanks in which coated, veneer rings were stacked. This system had several disadvantages.

Figure 7. Oyster larvae are cultured in 100 gallon conical, fibr eglass, reinforced-plastic tanks, each holding 2-5 million larvae.

Larvae set readily on the walls and sides of the tank and unevenly on the collectors, setting more densely on those at the bottom of the tank and preferring horizontal surfaces to vertical ones. Shallower tanks containing only one layer, of collectors and lined with FRP are now under test.

Growth of Spat

In the original concept of the operation of the hatchery, it was planned that spat would be put out into natural conditions immediately after setting. It was found in the early trials of 1964 that such small spat were very susceptible to silting and fouling, which caused high mortalities. It was obvious that spat would have to be protected from such dangers until they were large enough to survive them. Accordingly, in 1965 spat were kept in the hatchery for 3 – 4 weeks after setting, and fed on cultured food before being put out in natural conditions. This has produced most encouraging results. The first rearing of oysters treated in this way has reached, at the end of six months, a size equivalent to two years' normal growth in nature.

The oysters leave the hatchery as spat 1/8 – 1/4" in diameter fixed to the collectors, which are then suspended from floats in the estuary where growth continues under natural conditions. They are held this way until they can be separated from the collector and placed on trays in a suitable nursery area, or until they are large enough for separation and direct planting.

Space limitations have restricted spat growth in the hatchery to laboratory-sized lots. A unit for the intensive growth of spat is being designed and will be built in the near future. This will lead to the development of techniques of commercial scale.

Feeding of Larvae and Spat

Originally, it was intended that cultured foods would only be used for larval rearing in the winter and for supplementary feeding in poor seasons. The provision of such food assumed greater importance when the necessity to hold settled spat in the hatchery for some weeks was demonstrated.

The classical method of culturing the small plants which oyster larvae and spat use as food is in large glass containers of sterilized, enriched sea water, carefully shielded from outside contamination. This is a complex, technical process and expensive on the scale required for commercial spat rearing. A much less complex system which shows great promise has been developed at Ellerslie.

Stock cultures are maintained by classical methods. Cultures used for feeding are held in FRP tanks illuminated by fluorescent lights housed in plexiglass tubes which pass through the tank from side to side. The culture is continuously circulated by a pump through jets which play on the bottom of the tank. This ensures even illumination, prevents the cells from settling out, and also allows circulation through a cooling bath if necessary. Up to half of the volume of the tank can be taken for feeding every day. The tank is replenished with filtered enriched sea water.

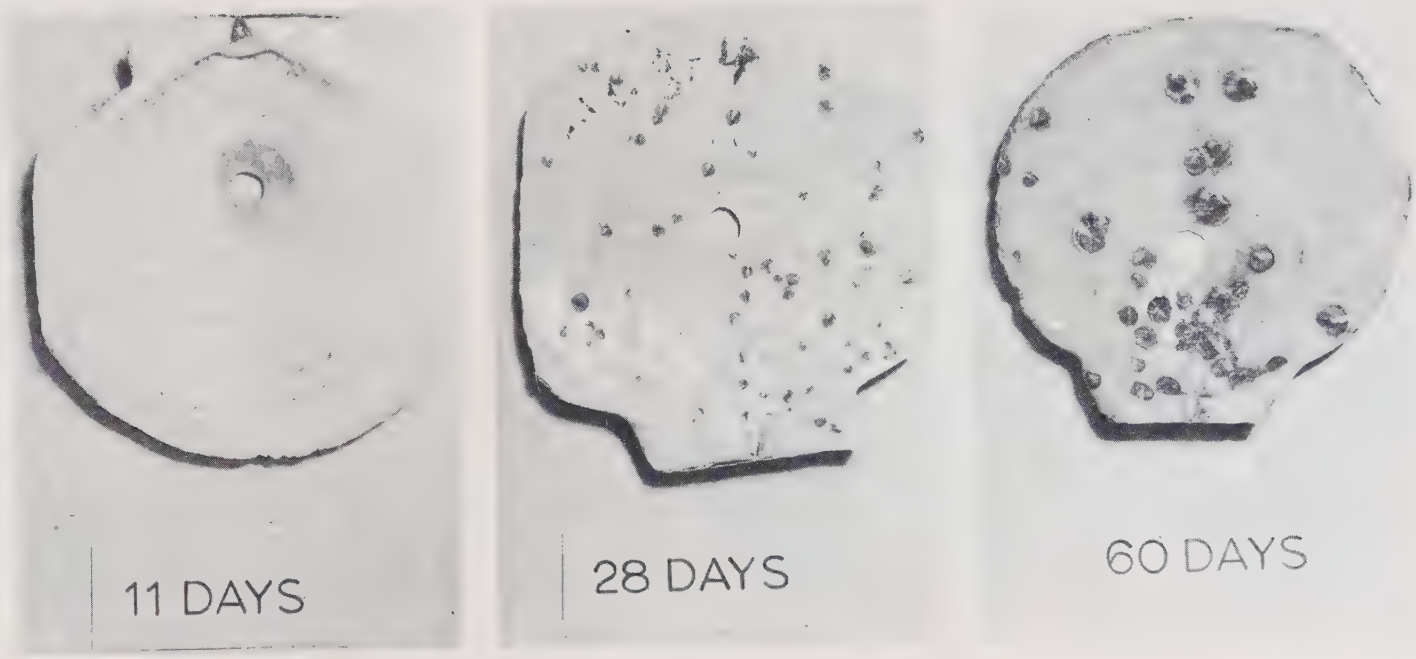

Figure 8. Growth stages in a commercial scale rearing in 1965, 11, 28, and 60 days old.

Cultures have been maintained for up to six months by this system. The spat which showed such good growth in 1965 were reared on cultured food in larval and early spat stages.

So far cultures have been harvested in bulk once daily. A continuous flow system, whereby a metered flow of sterile enriched sea water causes an overflow of culture directly into feeding tanks, is under development.

Even with the simplified system now used, the culture of plants for feeding is an undesirably costly practice in the hatchery. Some substitute food, preferably one which can be conveniently stored, would be extremely valuable. At Ellerslie, tests have been made using a number of vegetable leaves ground small enough to be eaten by larvae and spat. While some of these have shown some promise, no satisfactory substitute for the cultured foods has yet been developed.

Commercial Hatchery Development

The work at Ellerslie has demonstrated the feasibility of the biological processes involved in hatchery production of seed oysters, as well as some of the engineering problems involved. Neither the economic feasibility of the process nor its reliability over a long period has been established. The present situation indicates that a successful commercial oyster hatchery could become a reality in the near future. It should be stressed, however, that this is still an undertaking which involves a substantial degree of risk. The process, which is in the early stages of development, has not yet reached the "add oysters and stir" stage.

It is also important to realize that Canadian experience is limited to one locality. Experience in other countries has shown that some techniques may only be successful in the area in which they are developed. Ellerslie was chosen as the site for the Experimental Hatchery for convenience and from the greater knowledge of this area, rather than from any belief that this is the most promising site in the Maritimes. Though the area has a number of favourable characteristics, there are also some serious disadvantages. Alternative sites might have characteristics which would allow simplification of hatchery processes or demand alterations.

With these reservations in mind, some general conclusions can be drawn from experience so far.

In Eastern Canada, the aim of a hatchery operation must be to produce single, good shaped oysters of bedding size (1½ – 2"). These must be held under controlled, inside conditions until 1/8 – 1/4", after which they may be grown outside.

The materials in contact with sea water in the hatchery operation should be chemically inert if possible. Glass, polyethylene, polyvinyl chloride, and FRP have been shown to be suitable. Metals should be avoided, particularly copper and its alloys. Even sea water resistant stainless steel should be kept to an absolute minimum.

Plant sanitation is extremely important. All incoming water must be filtered. The sea water distribution system should be kept as short and simple as possi-

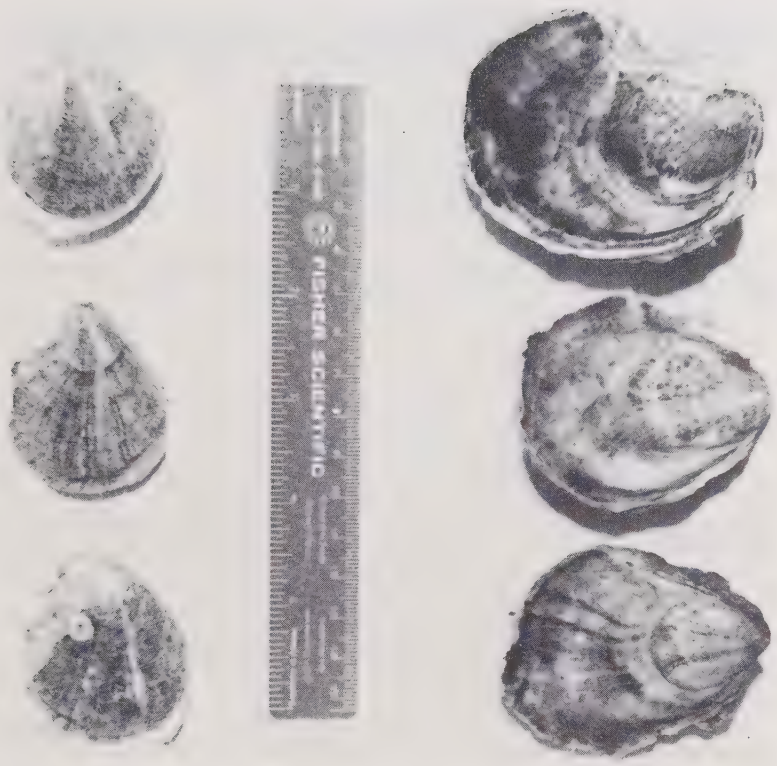

Figure 9. Growth stages in a commercial scale rearing in 1965, 6 and 18 months old.

ble, and so constructed that it can be quickly dismantled for cleaning.

At least one member of a hatchery staff must be trained in the necessary techniques and maintenance procedures. Some operations, e.g. food culture, require a good deal of technical ability, and all require care and attention to detail.

Although the present scheme has been shown to be feasible, it is unlikely to be the most economical or efficient which can be developed. There is a good deal of room for improvement in existing techniques or for the development of alternate ones. Some of these possibilities have already been mentioned, but there are others worth noting.

Commercial scale operations have so far been limited to the spring and summer, when a reasonable growing period was left for spat. Techniques allowing year-round operation of at least the larval rearing process, could greatly increase production.

The present method of rearing spat in the early stages is a relatively costly one. A simpler process would be of obvious advantage. The use of covered tanks containing filtered, fertilized sea water show great promise.

These and many other possibilities are being explored and will be investigated. The results will almost certainly bring about radical changes in hatchery techniques in the next few years.

Comparative Hooking Mortality Using Three Types of Terminal Gear on Rainbow Trout From Pennask Lake, British Columbia

by

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It is standard procedure for some anglers to hook and release trout after killing the daily limit, or to be selective from the outset, releasing fish under a preferred size, or to angle strictly for pleasure releasing the total catch. There is nothing basically wrong with this practice providing fishing pressure is light or hooking mortality negligible. Conversely, a high mortality on released fish may indicate a need for restrictive legislation to minimize hooking loss, particularly for waters supporting moderate to heavy fishing pressure. Moreover, all coastal streams in the province presently have an 8-inch size limit to protect downstream migrants, although fishing is permissible throughout the year.

At times sportsmen assert pressure for the enactment of gear restrictions—usually fly-fishing only—on the assumption that the fly is either a more sporting lure to use or that there is less injury to released fish. We have here a value judgement and a premise, but only the latter can be assessed quantitatively. Either argument may form the basis for legislation, but management agencies should appreciate which yardstick is used. Consequently, some knowledge of hooking mortality is necessary to formulate realistic trout regulations applicable to a particular fishery.

Material and Methods

In order to assess hooking mortality on rainbow trout *(Salmo gairdneri)*, a study was undertaken at Pennask lake in June 1963 and July 1964 using three types of terminal gear: fly, treble hook, and single hook plus worm behind a spoon or flasher. Flies used were size #8 and #10; the treble hook was size #8 attached directly to a flatfish or spoon; the single hook was size #8 with a short shank connected to a troll by an 8-inch nylon leader.

Standard fishing methods were simulated as much as possible whereby trout were hooked, played for 1-2 minutes and then netted. Use of needlenose pliers to remove hooks imbedded in the gill arch or esophagus and the cutting of the line when the hook could not be readily dislodged were two departures from what

was considered standard angling technique. Size of trout averaged 29.1 cm with a range of 19.9-34.4 cm, and the mean landing time was 1.5 minutes with a range from 1 to 2.5 minutes.

After landing, fish were held in the boat for brief periods in fry cans containing 5-8 gallons of water and then transferred to holding pens immediately offshore. Each pen was a wire enclosure with a wooden frame and plywood top and bottom having dimensions 8 feet long, 4 feet wide, and 3 feet deep, and emersed in 2 feet of water. Mortalities were recorded every 12 hours. It was unlikely that any loss occurred through suffocation. Maximum density per pen was 190. Surface temperature of lake at time of study was 15°C and 17°C for 1963 and 1964, respectively.

In 1963 some 67 trout from the treble hook sample and 69 trout from the single hook and worm sample were tagged with "chick wing" tags in order to compare mortality with area hooked. Tagging took place immediately after capture and before trout were placed in fry cans prior to transfer to holding pens.

The "chick wing" tag proved unsatisfactory as many came off either when fish came in contact with the side of the pen or when they were removed at the end of the observation period for identification and measuring. A 48-hour retention period was used in both 1963 and 1964.

In 1964 the single hook and worm phase of the study was duplicated to more accurately relate area hooked with subsequent survival. All trout were tagged through the dorsal musculature below the dorsal fin with Petersen disc tags without any subsequent tag loss. The procedure used in 1963 was followed.

Since a number of workers were involved in catching fish, hooking sites are general to compensate for differences in interpretation: upper jaw includes the maxilla and that area anterior to and including the palatine bone, whereas roof of mouth refers to the area between the palatine and the first gill arch; lower jaw includes the area anterior to the first gill arch, excluding tongue.

TABLE 1. Mortality of rainbow trout caught on three types of terminal gear during the observation period of 48 hours.

Year	Gear	Number Caught	Cumulative Mortality (hrs)				Percent Survival	
			12	24	36	48	Unadjusted	Adjusted
1963	fly	190	10	12	13	15	92.1	–
	treble hook..	145	2	3	4	4	97.2	–
	single hook with worm...	136	32	40	40	40	70.6	64.7
1964	single hook with worm...	103	32	43	44	46	55.4	54.4

TABLE 11. Area of hook penetration compared with mortality for tagged rainbow trout.

AREA	FLY		TREBLE HOOK		SINGLE HOOK 1963		SINGLE HOOK 1964	
	Number	Mortality	Number	Mortality	Number	Mortality	Number	Mortality
Esophagus	–	–	–	–	11	11	24	22
Lower Jaw	4	0	6	0	4	0	9	2
Upper Jaw	3	0	4	0	5	0	12	5
Upper and Lower Jaw	–	–	9	0	–	–	–	–
Roof of Mouth	–	–	–	–	3	1	15	3
Eye or Eye Socket	3	0	1	0	2	2	10	3
Corner of Mouth	1	0	19	1	5	1	23	3
Gill Arch	1	1	1	0	2	0	9	8
Tongue	–	–	–	–	3	2	1	1

Results

Table I gives the accumulated mortality, including adjustments for fish surviving after the line was cut. In 1963, seven trout lived for 48 hours with the hook in the esophagus and one with hook in gill arch, whereas in 1964 one survived with hook in the gill arch. All were untagged. Since the original intent was to simulate standard angling practice, it is assumed that most fishermen would recover the hook and thereby cause a lethal injury. These fish were hooked so deeply that it is unlikely that any would have survived hook removal, and they are added to mortality figures in the "adjusted" column.

A sample of 60 fish was held an additional 10 days without further loss, excepting one with a hook in the esophagus. Thus, it is improbable that an extended observation period would have altered results significantly. Most of the die-off occurs within 12 hours.

Chi-square tests were applied to ratios (Snedecor, 1956, p. 221), and a probability level of 0.01 was used as indicating significance.

Referring to Table I, there is no significant difference between survival of trout caught on fly or treble hook (chi-square = 3.2). However, the differences between unadjusted values for single hook versus fly and single hook versus treble hook are significant: single hook 1963 versus fly, chi-square = 24.7; single hook 1964 versus fly, chi-square = 52.7; single hook 1963 versus treble hook, chi-square = 35.7; single hook 1964 versus treble hook, chi-square = 63.1. There are no significant differences between unadjusted (chi-square = 5.3) and adjusted (chi-square = 2.2) single hook with worm samples for 1963 and 1964.

Table II compares area of hook penetration to subsequent survival of tagged trout. While tag recoveries for fly and treble hook samples are small this does not materially affect results because of low mortality for both groups. No fish from these groups were recorded as hooked in the esophagus, and only one from each sample was hooked in the gill arch.

Discussion

Although mortality may follow hyperactivity for some salmonids under certain conditions (Parker and Black, 1959) this possibility is ruled out as a cause of death. Black (1957) exercised rainbow trout in holding troughs without ensuing mortality, and the high survivals recorded for specific types of gear (Cartwright, unpublished data; Shetter and Allison, 1955) indicate that severity of wound is the principal factor contributing to death.

Cartwright (unpublished data) conducted a similar series of tests using rainbow trout from Bonaparte river, British Columbia, and he records mortalities of 2 per cent, 34 per cent, and 70 per cent for trout caught on fly, treble hook, and single hook plus worm, respectively. Sample sizes were as follows: fly - 48, treble hook - 31, and single hook plus worm - 50. Average size was 16.6 cm. Smaller fish and the fact that 27 (54 per cent) were hooked in the gill arch or esophagus without a single recovery accounts for part of the discrepancy for the bait data. The discrepancy between treble hook data for Pennask Lake and Bonaparte river is unexplainable, although differences in size of sample and size of fish may be partially responsible. It is possible that a treble hook causes more severe injury to a trout under 8 inches.

A consistent pattern emerges from results of a number of hooking mortality studies. Death from hooking with a fly is in the order of 10 per cent or less, whereas death from hooking with a single hook and worm is greater, and may vary from 30 to 70 per cent or more. The per cent mortality for bait caught samples will be determined, in part, by the area of hook penetration. Trout caught in the gill arch or esophagus generally die within a few hours of capture.

Table II suggests that trout are infrequently hooked in the back of the pharynx when using artificial lures, and this may reflect differences in behaviour patterns. Aggressive behaviour is contingent upon internal physiological state (Tinbergen, 1951) plus external stimuli, especially movement (Stringer and Hoar, 1955). Movement of the lure may set off the attack, terminating in a feeding and injesting response if bait were used or biting and rejecting if artificial lures were used. This suggestion is supported by the observation that trout are rarely hooked in the gullet when using flies. In addition, smell may contribute to frequent injesting of the single hook and worm.

It is concluded that capture and release of rainbow trout in British Columbia is not a serious problem because field observations indicate that most anglers, fishing strictly for sport or fishing after taking their daily limit, are generally using artificial lures, especially flies. Nevertheless, size regulations enacted to protect juvenile or migrant salmonids should be complemented with gear restric-

tions if bait fishing were prevalent and if an appreciable segment of the population were affected. Moreover, it may be expedient in future to allow catching but not keeping of trout in lakes adjacent to large urban developments, and if this were to happen bait restrictions should be imposed to minimize throwback mortality. Some restrictive regulations suggested by sportsmen favour fly-fishing, but this can be supported only in terms of aesthetic values or personal preference. These data, however, provide no biological basis for discriminating between use of artificial lures such as flies, flatfish, or spoons when angling.

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Studies on the Early Feeding of Sockeye Salmon Alevins[1]

by

Lawrence M. Dill

Abstract

A study of migrant sockeye salmon fry *(Oncorhynchus nerka)* showed that those from an incubation channel (Nanika River, B.C.) weighed 10% less than those from a natural environment (Fifteen-mile Creek, Babine Lake, B.C.), even though both were of the same genetic stock. The possibility of different patterns of early feeding by the fry was explored as the cause of this observed weight difference.

Random samples of these migrating fry were taken at intervals. The technique used was to compare the weight gain of the fish (i.e. alevin minus yolk sac) and the weight loss of the yolk over a time interval. Knowing the yolk weight loss and an estimate of the efficiency of conversion of yolk to embryonic tissue, the expected fish weight gain during the interval was calculated. The actual weight gain of the natural fry was significantly larger than the expected weight gain and it is apparent that these fish were utilizing an exogenous food supply prior to complete yolk absorption; this was not true of fish from the incubation channel. A comparison of the two environments indicates that physical factors alone could not have been responsible for the observed weight differences. Feeding by the Fifteen-mile Creek fry is considered to be a direct result of the presence of more food in that situation. The significance of these findings to the subsequent survival of the fry is considered.

Introduction

For many years it has been common practice to feed hatchery salmonids prior to the complete absorption of their yolk sacs. Henshall (1904) considered it wise to begin the feeding of fry before complete yolk absorption believing that the fry would then be much stronger when the sac was finally absorbed and in better condition to take and to assimilate artificial food. Henshall (1907) also reported that Montana grayling fry *(Thymallus montanus)* would eat fresh blood before their yolk sac was entirely absorbed.

Leach (1923a) reported that brook trout fry *(Salvelinus fontinalis)* began to feed as soon as the yolk sac was small enough to allow the fish to swim up, and that grayling fry (Leach, 1923b) began searching for food about one week after hatching.

[1]Based on a thesis submitted by the author in partial fulfillment of the requirements for the degree of Bachelor of Science at the University of British Columbia.

On the other hand, Atkins (1905) indicated that an early food supply might not be as important as might be supposed. He reported higher mortality in brook trout and coho salmon *(Oncorhynchus kisutch)* fed early than in those denied food for five days after hatching. Fasts of duration greater than five days increased the mortality in brook and lake trout but not in coho salmon.

Brown and Buck (1939) studied the time of first feeding in trout and grayling fry held in hatchery troughs and found considerable variation between species. Brown-trout fry *(Salmo trutta)* began taking food on the twenty-seventh day after hatching; rainbow-trout fry *(Salmo gairdnerii irideus)* on the fifteenth day; brook-trout fry *(Salvelinus fontinalis)* on the twenty-second day; and grayling fry *(Thymallus montanus)* on the third day after hatching. The yolk sack was still present in all cases.

Although it is fairly common practice to feed hatchery fry before the complete absorption of their yolk sacs, there is little published evidence that salmonids under natural conditions feed before complete yolk absorption. Disler (1953) reported that fry of the Amur Autumn chum salmon *(Oncorhynchus keta)* feed exogenously while still utilizing endogenous food supplies (i.e. yolk). The larvae are said to eat detritus, diatoms, *Cyclops*, and larval chironomids. The lengths of the fry at this stage were reported to be 30-33 mm. Nikolsky (personal communication) believes that pink salmon alevins *(Oncorhynchus gorbuscha)* may feed under the gravel in certain years and that their food consists of small copepods.

Burrows (personal communication) sampled chinook salmon fry *(Oncorhynchus tshawytscha)* emerging from the gravel of the Abernathy Incubation Channel at Abernathy, Washington, and found that 85 per cent of them had been feeding on "plankton" in the gravel. Similarly, it has been found that coho salmon feed well before complete yolk absorption, the food apparently consisting of stonefly larvae and detritus (Phillips, personal communication). Further details are unavailable. Hurley (personal communication) believes that sockeye fry *(Oncorhynchus nerka)* will take food at about 1,200 temperature units. His data showed that the yolk sac was not completely absorbed until the fish had received 1,800 temperature units. Harvey (1965) also found that sockeye salmon would accept food prior to yolk absorption and emergence, but that early feeding was not essential to the fry's subsequent development.

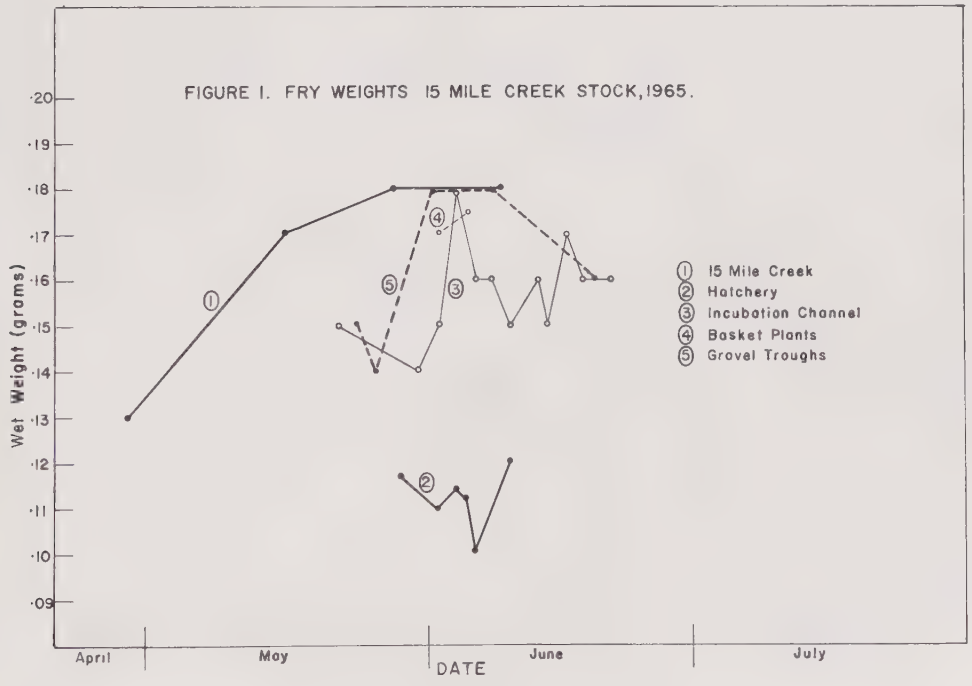
The present study is divided into two parts. Observations will first be presented to demonstrate that incubation channel fry are smaller than fry from a natural stream. The difference in weights between the channel fry and the natural fry poses an interesting question, for it has been assumed by Fisheries biologists that incubation channels provide the fish with conditions as close as possible to natural. However, some factor or combination of factors has been responsible for these weight differences, since the fish are of the same genetic stock. Secondly, the possibility of different patterns of early feeding by the fry will be explored as the cause of this observed weight difference.

Methods and Materials

I. Preliminary Studies

From November 1 to November 4, 1964, 1.4 million eyed sockeye eggs were planted in an incubation channel on the Nanika River, a tributary of the Morice River in Northern British Columbia, by Department of Fisheries personnel. These eggs were taken from spawners in Fifteen-Mile Creek on Babine Lake during a two week period in September and planted in the channel, which was in its first year of operation. During the spring of 1965, the Fish Culture Branch of the Canadian Department of Fisheries undertook an assessment of this channel. Some 1,181,000 fry emerged from the incubation channel, representing an egg to fry survival of 84 per cent. The channel is eight feet wide and parallels the Nanika River for 1,000 feet. Water is obtained from the Nanika River and the flow can be regulated with stoplogs.

The fry were sampled in a Wolf trap (an inclined plane, with a live box set across the full width of the channel) at the lower end of the incubation channel. A second Wolf trap was placed at the upper end of the incubation channel to prevent native Nanika River fry from entering the channel and invalidating the assessment program. Almost all of the fry emerged at night, and periodic samples of these migrant fry were taken and their wet weights compared with the wet weights of migrant fry from Fifteen-Mile Creek, the parent stream. Temperature records were also taken from each stream and the mean daily temperatures calculated from the daily maximum and minimum temperatures.



II. Experimental Studies

Fry raised in three different environmental situations were collected in the spring of 1965 and subsequently studied.

(1) Fifteen-Mile Creek - natural conditions. Fry samples: April 29 (removed from the gravel with a hydraulic sampler); May 16 (taken in fyke nets set in the stream overnight); May 28 (fyke nets); June 9 (captured in a Tsolum trap, a small inclined plane with a live box set in the creek overnight).

(2) Incubation Channel - eyed eggs planted. Fry samples: May 22, May 31, June 16 (all taken in a Wolf trap at night).

(3) Incubation Channel basket plants - 200 eyed eggs placed in a gravel-filled wire mesh basket (6" x 6") and placed beneath the gravel of the channel. Samples taken: May 9, June 2, June 5.

The fry were placed in 10 per cent formalin. During the following winter, samples, usually of 20 fish, were blotted dry and their yolk sacs carefully removed with a dissecting needle. This was facilitated by the hardening effect of the formalin. Oil droplets adhered to the hardened yolk and were removed with it. The yolk and the fish were placed in separate petri dishes and dried in a 36°C oven for 24 hours. One hour after removal from the oven, the yolk and fish samples were weighed separately on a microanalytical balance and the weights recorded. In this manner, two samples of fry were done on the same day and the results compared.

The weight loss of the yolk material was calculated for the period between the dates on which the two samples were taken. As the water temperature was

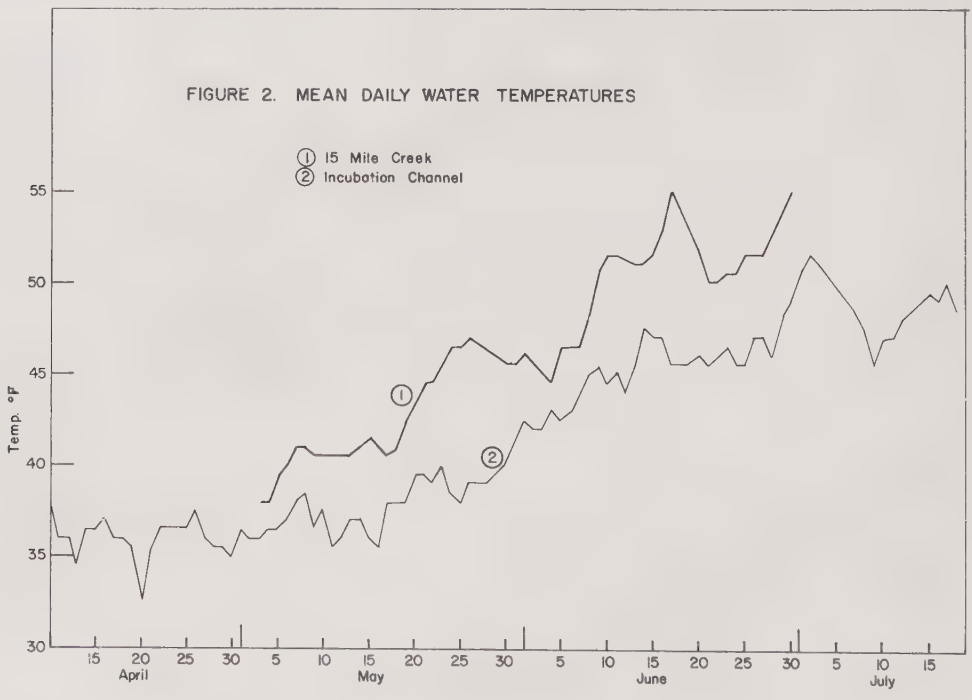


Table 1
Weight changes (grams) in three environmental situations.

Location	SAMPLE 1					SAMPLE 2					COMPARISON							Remarks
	Date	Number in sample	Mean yolk wt.	Mean fish wt.	Mean total wt.	Date	Number in sample	Mean yolk wt.	Mean fish wt.	Mean total wt.	Total wt. change	Yolk wt. loss	Temp. °F	Expected fish gain	Actual fish gain	Excess wt. gain	% excess	
Fifteen-Mile Creek	April 29	20	.0192	.0129	.0321	May 16	20	.0078	.0194	.0272	−.0049	.0114	38	.0048	.0065	.0017	35	
		20	.0192	.0129	.0321		20	.0076	.0189	.0265	−.0056	.0116	38	.0048	.0060	.0012	25	
		20	.0253	.0108	.0361		20	.0106	.0196	.0302	−.0059	.0147	38	.0062	.0088	.0028	42	
		20	.0238	.0129	.0367		20	.0158	.0181	.0339	−.0028	.0080	38	.0034	.0052	.0018	51	
	May 28	20	.0081	.0243	.0324	June 9	20	.0053	.0285	.0338	+.0014	.0028	45	.0013	.0042	.0029	221	Total wt. gain
		20	.0101	.0239	.0340		20	.0055	.0285	.0340	nil	.0046	45	.0021	.0046	.0025	119	No net change
		20	.0081	.0239	.0320		20	.0042	.0277	.0319	−.0001	.0039	45	.0018	.0038	.0020	111	No net change
Incubation channel	May 22	49	.0080	.0200	.0280	June 16	62	.0010	.0230	.0240	−.0040	.0070	42	.0030	.0030	nil	nil	
	May 31	20	.0032	.0228	.0260	June 14	20	.0003	.0228	.0231	−.0029	.0029	44	.0013	nil	nil	nil	No fish gain
		20	.0034	.0239	.0273		20	.0001	.0214	.0215	−.0058	.0033	44	.0015	nil	nil	nil	Fish lot loss
Basket plants	May 9	133	.0143	.0227	.0370	June 2	40	.0036	.0247	.0283	−.0087	.0107	38	.0045	.0020	nil	nil	
		133	.0143	.0227	.0370	June 5	40	.0025	.0268	.0293	−.0077	.0118	39	.0050	.0041	nil	nil	

Table 11
Control samples (dry weights, in grams).

Location of capture	Date of capture	Number in sample	Average yolk weight	Average fish weight	Average total weight
Fifteen-Mile Creek	June 9	20	.0055	.0285	.0340
		20	.0053	.0285	.0338
	April 29	20	.0240	.0138	.0378
		20	.0253	.0128	.0381
	May 28	20	.0107	.0216	.0323
		20	.0096	.0220	.0316
Incubation channel	May 31	20	.0043	.0202	.0245
		20	.0038	.0200	.0238
Basket plant	June 5	20	.0026	.0288	.0314
		20	.0025	.0283	.0308

known during the period, the percentage of this weight loss which could have been incorporated into embryonic tissue was calculated using Hayes and Pelluet's data (1945). The theoretical weight gain thus calculated was compared to the actual weight gain of the fish during the period and the excess, if any, recorded as a percentage of the expected weight gain. A discussion of the applicability of Hayes and Pelluet's data will be given below.

One sample of fry from Fifteen-Mile Creek was analyzed on the basis of both wet weights and dry weights.

Control tests were also made. These consisted of taking two samples of 20 fish from a larger sample of fish all taken on the same day. These samples were treated in the same way as the experimental fish.

In addition, 54 fish from various sources were examined for possible stomach contents. The intestine was too small to permit gross examination. Stomachs were examined by two methods: dissection of stomach under binocular microscope– 52 fish; and staining with haematoxylin and eosin after microtome sectioning–two fish.

Results

I. Preliminary Studies

The results of the weight comparison can be seen in Figure 1. Each sample represents 50 fish. The peak periods of fry migration from the incubation channel were the nights of June 15 (105,854 fry) and June 16 (111,702 fry). Fish sampled

Table 111
Results of stomach sample analysis.

Location	Date		Method	Number in sample	Results
	Captured	Examined			
Incubation channel	May 9/65	May 9/65	Gross disection	3	No food seen
	May 9/65	May 11/65	Gross disection	5	No food seen
	June 21/65	Aug. 1/65	Sectioning	1	No food seen
Fifteen-Mile Creek	April 29/65	May 17/65	Gross disection	15	No food seen
	April 29/65	Aug. 1/65	Sectioning	1	No food seen
	May 16/65	May 17/65	Gross disection	10	No food seen
	May 16/65	May 18/65	Gross disection	6	No food seen
	May 28/65	Feb. 7/66	Gross disection	3	No food seen
	June 9/65	Feb. 8/66	Gross disection	4	No food seen
Nanika River	June 29/65	May 13/65	Gross disection	6	Food seen in 1 fish

at that time averaged approximately 0.16 grams. The Fifteen-Mile Creek fry had reached and maintained a weight of 0.18 grams by May 28. The incubation channel fry were consistently smaller, with the exception of 24,400 fry taken on June 4, a sample of which averaged 0.18 grams. After June 4 the weights of the channel fry fell off and averaged approximately 0.16 grams from then until the end of the migration period. It can also be seen from the graph that a third lot of fry, those from the Nanika River Hatchery, were significantly smaller than either channel or natural fry.

A comparison of the mean daily water temperatures in Fifteen-Mile Creek and in the incubation channel is shown in Figure 2. The temperatures recorded in Fifteen-Mile Creek are consistently higher than those recorded in the incubation channel.

II. Experimental Studies

The results of the experimental studies, summarized in Table I, demonstrated that the fish (i.e. alevins minus yolk sacs) from Fifteen-Mile Creek gained weight which cannot all have been the result of yolk utilization, since there was an excess weight gain, i.e. actual weight gain minus expected weight gain. From April 29 to May 16 this excess weight gain amounted to 25-51 per cent of the actual fish weight gain. The entire alevin (yolk included) lost weight during

this time interval. From May 28 to June 9 the excess weight gain amounted to 111-221 per cent of the fish weight gain. During this time period, however, the fish did not decrease in total weight. (Student's t showed no significance between dates decrease at the .05 level). In all cases, the fish from the incubation channel had gained no excess body weight. In other words, all the body weight gain can be accounted for by yolk sac utilization. The results were the same for fish captured while migrating out of the channel (recorded as "Incubation Channel" in Table 1) or removed from baskets in the channel (recorded as "Basket Plants" in Table 1).

The results of the control experiments are summarized in Table 2. It is obvious that the differences between the paired samples are insignificant in all five cases.

The results of the stomach sampling are shown in Table 3. The food in the one Nanika fish appeared to be a small crustacean.

Dry weights were also compared with wet weights for one of the samples with results as shown below.

Table 4. Wet and dry weight comparison.

Total weight	May 22	June 16
Wet	0.108	0.131
Dry	0.027	0.024

Discussion

All the Fifteen-Mile-Creek fish lost weight from April 29 to May 16. Presumably, this was because the exogenous food intake was not equal to one-half the amount of yolk utilized. If, for example, the yolk loss in an interval is 0.0010 grams, the amount available for growth, if we assume 50 per cent efficiency of conversion to embryonic tissue, is 0.0005 grams. The entire alevin will not gain weight unless the food digested and assimilated in the interval is greater than 0.0005 grams, since 0.0005 grams of food is required to make up for that amount of yolk used in maintenance. From May 28 to June 9, however, the total weight of the fish remained constant. The fact that the total weight was not decreasing is itself indicative of feeding, since utilization of the yolk would otherwise have an efficiency in excess of 100 per cent. The incubation channel fry show no excess weight gain. Thus, it appears that the Fifteen-Mile-Creek fry were feeding prior to emergence while those in the incubation channel were not. Whether this feeding occurred in the gravel or during short excursions from the gravel is uncertain.

It should be stressed at this point that the validity of our conclusions rests upon the applicability of Hayes and Pelluet's efficiency constants to the material we have used. The work of these authors was carried out on the embryos of the Atlantic salmon *(Salmo salar)*. We cannot be certain that their results are

applicable to sockeye salmon *(Oncorhynchus nerka)*. Their experiments were carried out in a laboratory and the experimental conditions, e.g. water flow, are not given. However, Gray (1926) gives the efficiency of development of brown trout *(Salmo fario)* as 63 per cent at 10°C. Furthermore, Gray points out that this value seems to be consistent with the efficiency coefficients of other organisms. He lists these as follows: *Aspergillus*, 59% (.59); silkworm, 59% (.59); frog, 58% (.58); chick, 63% (.63). Hayes and Pelluet's efficiency coeffi- reaches 58 per cent at about 16°C. Considering the consistency within all biological material, therefore, it seems safe to assume approximate applicability of Hayes and Pelluet's data to sockeye salmon.

Although the control samples showed the consistency of technique in a particular weighing day, differences exist between the weights of two identical samples weighed on different days. Since selection of the fish was as random as possible, differences in handling technique are thought to be responsible for the between samples differences. Although standardization was attempted, there were unavoidable differences in some cases. For example, on some days there were longer delays between weighing and drying than on other days. During this interval the embryo and yolk sac may have taken up water. In all cases, however, comparison of two weighed lots was made only if the two samples were dissected, dried and weighed on the same day. The consistency of the final results appears to indicate validity of this technique.

The importance of drying the samples should be emphasized. A comparison of wet and dry weights was made in Table 4. The comparison reveals that, during development, the embryo takes up a considerable amount of water. Brannon (1965) considers this to be due to a decrease in lipid content. As the table showed, the conclusions reached depend on the type of weight used. Thus, when Vibert (1953) tells us that fry hatched under gravel are 15 per cent heavier than hatchery reared fry, we cannot be sure of the effect of gravel cover, since Vibert compared wet weights. There may have been some other environmental factor, perhaps solar radiation, which caused increased water uptake in one situation and not in the other.

The possibility exists that other factors may have been responsible for at least part of the excess weight gain recorded in the Fifteen-Mile-Creek fry. Other factors cannot be solely responsible, however, since, in some cases, this would require the yolk conversion efficiency to be in excess of 100 per cent (May 28 to June 9). However, we cannot discount the possibility that some environmental variable has increased the efficiency of conversion in Fifteen-Mile-Creek alevins.

Temperature has been shown to affect the efficiency of conversion of yolk to embryonic tissue. Although temperatures are higher in Fifteen-Mile-Creek, this variable has been corrected in the calculations, however, by relating efficiency to temperature.

The oxygen content of the water may increase the food coefficient (Winberg, 1956). Presumably, therefore, it may affect the efficiency of yolk conversion in a similar manner. Brannon (1965) concluded that low oxygen levels resulted in retardation of growth and yolk utilization. Studies have shown that at least the

surface water in the Nanika Incubation Channel is saturated with oxygen. Considering the shallow depth of the channel (one to two feet in most places), the water is probably saturated with oxygen throughout. Fifteen-Mile-Creek, because of its finer gravel cover and greater depth, probably contains less oxygen in the gravel. Furthermore, estimated fry densities are higher in Fifteen-Mile-Creek than in the incubation channel. In any case, there is no more dissolved oxygen than is present in the incubation channel. Apparently, differences in concentrations of dissolved oxygen do not account for the observed differences in weight changes in the two environments.

Gravel cover, apparently, may increase the weights of fry (Vibert, 1953). As discussed above, however, this increase may have been due to some other factor. In any case, in the present experiments, both environmental situations were similar to the extent that both were gravel covered. The gravel size in the channel was graded, the smallest gravel being 3/8 inch. Gravel in Fifteen-Mile-Creek varied more and contained much smaller material. We might suppose that the packing of the small gravel may reduce the availability of oxygen, thereby decreasing the yolk efficiency coefficient. On the other hand, the decreased velocity would increase this coefficient. The net effect would be small. Therefore, we may reject differences in gravel cover as factors causing increased yolk conversion efficiency.

Solar radiation is probably not a factor, since both of the situations studied were gravel covered. Furthermore, Brannon (1965) feels that solar radiation does not affect the rate of yolk utilization, even though Eisler (1957) reported that salmon larvae raised in artificial light were slower in absorbing their yolk sacs.

Increased water velocity causes increased activity in the fish and decreases the efficiency coefficient, since more energy must be used for maintenance (Brannon, 1965). However, velocities in the incubation channel were lower, yet weights were less. Smaller gravel cover in Fifteen-Mile-Creek may have decreased the water velocity in the gravel, although this seems unlikely. The gravel there was scouring at the time of collection, and intra-gravel velocity was probably high. Therefore, velocity differences, apparently, have not caused increased efficiency coefficients in the Fifteen-Mile-Creek alevins.

We now come to the following question: If the Fifteen-Mile-Creek fry are feeding, why can no food be found in their stomachs? The most plausible reason is that the fish perhaps fed early in the day and most material may have been digested by the time of capture.

Why are the Fifteen-Mile-Creek fry feeding and the incubation channel fry not feeding? The smaller gravel in Fifteen-Mile-Creek may be responsible, since it may provide more lodgings for food organisms. Secondly, the incubation channel was in its first year of operation, having been completed and flooded in October 1964. Therefore, it may not have had time to build up a fauna prior to fry emergence.

What is the significance of early feeding? As mentioned above, Henshall (1904) believes that it promotes better feeding after emergence. Although Henshall was referring to hatchery reared fish the same is probably true under natural conditions.

Palmer et al. (1951) found that a retardation in the time of initial feeding of salmon fingerlings has a depressing effect on the growth rate. Thus, pre-emergent feeding may increase the subsequent growth rate of the fish.

We may also hypothesize that early feeding of the fry may be part of a learning process, conditioning the fish for post-emergent feeding. If this theory is correct, the food need not necessarily be digested. The results indicate, however, that the food is indeed digested and assimilated.

Summary

1. A comparison of wet weights shows that fry emerging from a natural condition are larger than fry emerging from an incubation channel.
2. Experiments show that the natural fry gain weight which cannot be accounted for from the yolk sac alone.
3. A comparison of the two physical environments shows that these factors, temperature, oxygen content, gravel cover, solar radiation, and velocity, could not have resulted in the excess weight gains.
4. It is concluded that fish in the natural situation have fed prior to emergence, while those in the incubation channel have not.
5. Feeding in the natural situation is considered to be a direct result of the presence of more food in that situation.

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Movement of Planted Hatchery-Reared Trout from a Natural Lake

by

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Abstract

Extent to which hatchery-reared underyearling and yearling brook and rainbow trout in 21 plantings attempted to leave Crecy Lake, New Brunswick, was determined by year-round operation of a trap on the outlet. A greater proportion of brook than rainbow trout left the lake. Yearlings of both species, particularly those maturing, were most prone to run. Most prominent runs were associated with greatest water discharge from the lake.

Introduction

Investigations were carried out at Crecy Lake, New Brunswick, with the object to improve angling for brook trout (*Salvelinus fontinalis* (Mitchill)) and rainbow trout (*Salmo gairdneri* Richardson) by fertilization of the lake, exercising predator control and stocking with hatchery-reared trout (Smith, 1955, 1956, 1960).

When the objective in stocking a lake, as was the case at Crecy, is primarily to increase the supply of trout in that particular lake, dispersal of the planted stock at and subsequent to the time of planting is of definite concern, especially movement of fish into the outlet, which would probably result in their loss to the stocked lake. (Depending upon conditions, such fish are of course not necessarily lost to anglers elsewhere.) Smith (1944) observed that hatchery-reared, underyearling (age 0) brook trout planted in autumn in Bonaparte and Limeburner Lakes, neighbouring to Crecy, dispersed quickly from planting at single shore points. Within a day, planted underyearlings were found in the lake inlets and in the case of Limeburner, in the outlet. In these cases, and subsequently at Crecy Lake, the various stocks of planted trout were made identifiable by fin-clipping.

Crecy Lake

Crecy is a head-water lake of 50 acres (20 ha), tributary to the Bocabec River System, Charlotte County, New Brunswick (67°0'' W long, 45°14'' N lat). The lake has maximum and mean depths of 12.5 and 7.8 feet, respectively (3.8 and 2.4 m). A hydrological description of the lake has been given by Smith (1952).

Little water flows in the outlet in late summer and late winter. In 1960, for instance, no water flowed from the lake in August and early September.

Crecy Lake has no permanent inlet streams. The outlet, therefore, presented the only running water in which mature trout might spawn. However, both planted brook and rainbow dug shallow redds and spawned in littoral areas of Crecy Lake where there was a mixture of quite firmly packed sand and gravel. Spawning in these situations met with at least moderate success (Smith, 1955). In the spring of 1951, for instance, shore counts provided an estimate of 5,000 naturally-produced brook trout fry. As judged from angling records and by observations of trout on the redds, there were few naturally-reared brook trout in the lake to have been possible parents of the observed fry.

Temporary eutrophication of the lake was realized with fertilization, and the food supply, particularly in the bottom fauna, for trout was increased (Smith, 1948, 1955, 1961). Control of fish-eating birds and mammals was exercised over the period 1949-63, and this, coupled with fertilization, markedly improved the yield of planted trout to anglers (Smith, 1955, 1963).

Data and Their Collection

Tables I and II provide data on the numbers of brook and rainbow trout from 21 plantings which moved into Crecy Lake outlet. Twelve of the plantings consisted of underyearling (age 0) and the other 9, of yearling (age I) trout.

During much of the investigation of 1950-63, a trap was maintained in the outlet just below its discharge from the lake throughout each year, and attended by a technician resident at the lake. The primary purpose of the trap was to prevent escapement of planted trout from the lake in a program of stocking, fertilization, and predator control to improve trout angling at Crecy Lake. However, there was the opportunity to learn to what extent planted trout attempted to leave the lake via the outlet. The straining surfaces of the trap consisted of ¼-inch galvanized wire mesh, adequate to prevent escapement of trout of the size in the several plantings.

Trout captured in the outlet trap were returned to the lake, usually at some distance from the outlet. However, an unknown number of trout, particularly among those planted as yearlings, were doubtless captured more than once. Accordingly, numbers of trout given in Tables I and II are greater than the actual numbers of different trout involved in the movements.

Factors Involved in Movement of Trout Into Crecy Outlet

Tables I and II show that there was much variability in the proportion of trout from the several plantings that attempted to leave the lake. Certainly, a number of factors were involved in the movements, some specific to the fish, and others related to the environment. Some conditions associated with running of trout from the lake are discussed. It is not inferred, however, that the associations necessarily designate cause and effect.

Species of trout

A greater proportion of the brook than of the rainbow trout underyearlings ($p = .01$) attempted to leave Crecy Lake. Differences in the proportions of year-

Table I. Numbers of planted hatchery-reared brook trout leaving Crecy Lake by months following each planting and as percentages of the numbers planted. (1 cm =0.39 in.)

Planting date	Planted as underyearlings (age 0)							Planted as yearlings (age I)						
	Sept. 12 1950	Sept. 7 1951	Sept. 5 1952	Sept. 9 1953	Sept. 8 1954	Sept. 8 1955	Sept. 13 1956	Aug. 24 1950	Sept. 5 1951	Nov. 2 1951	Sept. 2 1952	Oct. 28 1952	Sept. 10 1953	Nov. 3 1953
Average fork length (cm)	8.4	8.2	6.7	7.5	10.8	8.5	9.5	19.3	17.3	24.8	20.8	26.0	19.7	24.8
Taken in trap														
Sept.	25	39	6	16	14	5	5	...	1	...	...	...	...	...
Oct.	45	13	10	42	264	7	7	...	26	...	...	...	79	...
Nov.	72	56	...	38	1355	24	35	38	188	33	32	37	387	475
Dec.	...	25	6	61	394	7	318	1	6	1	6	21	20	51
Jan.	2	1	...	8	23	3	31	2	2	...	1	...	4	...
Feb.	2	2	2	3	20	3	9	...	3	...	1	...	...	3
Mar.	...	...	...	1	27	...	7	...	...	...	...	...	13	28
Apr.	2	...	1	3	21	1	5	...	...	...	...	...	9	1
May	1	...	1	...	2	14	4	...	...	...	...	...	1	...
June	...	2	...	1	...	1	1	...	...	...	...	...	...	...
July	...	...	...	...	2	...	...	...	...	...	...	...	...	...
Aug.	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sept.	...	...	1	...	...	...	...	...	...	...	...	...	...	...
Oct.	29	...	60	13	1	1	8	...	...	...	...	...	...	...
Nov.	200	21	96	9	9	3	...	...	...	...	...	...	...	...
Dec.	1	2	2	1	...	1	...	...	...	...	...	...	...	...
Later	...	1	...	...	...	...	...	...	...	...	...	...	...	...
Total	379	162	185	196	2132	70	430	41	226	34	40	58	513	558
Number planted	6750	14160	13440	13390	13230	13650	12970	674	675	674	675	675	673	675
% of number planted	5.6	1.1	1.4	1.5	16.1	0.5	3.3	6.1	33.5	5.0	5.9	8.6	76.2	82.7
% running while underyearlings (age 0)	2.2	1.0	1.2	1.4	16.0	0.5	3.2							

Table II. Numbers of planted hatchery-reared rainbow trout leaving Crecy Lake by months following each planting and as percentages of the numbers planted. (1 cm = 0.39 in.)

Planting date	Planted as underyearlings (age 0)					Planted as yearlings (age I)	
	Sept. 8 1958	Oct. 6 1959	Oct. 4 1960	Oct. 11 1961	Oct. 2 1962	Oct. 16 1959	Oct. 4 1960
Average fork length (cm)	6.4	7.6	10.6	9.2	9.5	19.7	17.6
Taken in trap							
Sept.	15	...	...	...	...	...	...
Oct.	22	11	...	12	22	7	...
Nov.	4	12	8	68	3	2	...
Dec.	3	3	2	1	...	...	...
Jan.	1	1	2	1	...	3	...
Feb.	1	27	2	...	8	...	...
Mar.	1	15	6	...	1	...	...
Apr.	1	1	2	...	...	9	...
May	1	1	38	1	...	24	72
June	3	...	7	...	...	...	12
July	...	...	...	...	...	...	...
Aug.	...	...	...	...	...	...	...
Sept.	...	...	...	...	3	...	...
Oct.	1	...	...	...	4	...	...
Nov.	3	...	...	...	...	...	...
Dec.	1	...	...	...	...	...	...
Later	...	3	1	...	...	...	3
Total	57	74	68	83	41	45	87
Number planted	13650	13500	13420	13550	13500	1561	1350
% of number planted	0.4	0.5	0.5	0.6	0.3	2.9	6.4

lings are not statistically significant ($p = .32$), with only two plantings of yearling rainbow trout. There is a general opinion that rainbow trout planted in Maritime lakes have a definite tendency to run from the lake of planting.

Size and maturity of planted trout

Table I shows that in general a greater proportion of brook trout planted as yearlings attempted to leave Crecy Lake than when planted as underyearlings ($p = .012$). The difference is best illustrated between underyearlings and yearlings planted in the same year. A similar situation seemed to occur with rainbow trout, but the sample is too small for statistical analysis (Table II). Observations are available to indicate, however, that size in itself was perhaps not as dominant a factor in running from the lake as stage of maturity.

In 1951, and again in 1953, the planted yearling stocks consisted almost entirely of males which were mature in the autumn of planting. Coincident was a high proportion of the planted yearlings attempting to leave the lake. In October 1952, the yearlings were the largest of any which were planted, but for the most part these fish had been artificially spawned at the hatchery prior to being transferred to Crecy Lake. In other years, the planted yearlings consisted of both sexes and more immature individuals. Coincident with these later cases was a lower proportion of the yearlings moving into the outlet.

The rainbow trout planted in Crecy Lake were spring spawners. Table II shows that most of the planted yearling rainbow trout which attempted to leave the lake did so in the spring rather than in the autumn of planting. These spring movements were associated with maturity of the fish.

It is pertinent that angling pressure on Crecy Lake was sufficiently heavy to remove almost all of the planted yearling brook trout during the angling season following introduction, that is when the fish were age II (Smith, 1955). Angling mortality was also high among the planted underyearlings (age 0) when they became yearlings (age I). However, numbers of these fish survived through the first angling season to which they were subjected (Smith, 1960). Some of these yearlings matured, and Table I shows that fish from the underyearling plantings attempted to escape from the lake during the autumn a year after being introduced into the lake.

Environmental factors

The majority of the movements by brook trout into the outlet (underyearlings and yearlings) were in autumn and early winter, and these movements were associated with high lake discharge. The numbers of brook trout attempting to leave the lake are given on a monthly basis in Table I. However, it can be shown that the greater number actually attempted to leave on a few days when heavy rainfall sharply increased discharge from the lake. For instance, 161 planted trout attempted to leave the lake on November 24, 1953, after heavy rain had increased the depth of water in the outlet from 2.5 to 8.5 cm (2.54 cm = 1 inch). Again, 149 trout left the lake when, as a result of rains, the depth of water in the outlet increased from 3.3 to 10.5 cm. on November 17, 1954.

Most of the brook trout, whether planted as underyearlings or yearlings, moved into the outlet with the high water of autumn and early winter, rather than with the recurrence of heavy lake discharge in spring. Brook trout are fall spawners and the contributing factor of maturity in running has been suggested. Immature brook trout were very actively feeding in the lake in spring and this activity may have been a factor in fewer of these fish leaving the lake at that season. Much the same was observed for the rainbow trout planted as underyearlings (TableII). As noted, however, the rainbow trout are spring spawners, and associated with maturity among a portion of this species planted as yearlings is movement from the lake with the spring high water when they were age II.

The proportion of brook trout underyearlings moving into the outlet traps from the planting made on September 8, 1954, was decidedly greater than was the case with the other comparable introductions. This specific event was associated (1) with above-average rainfall in late autumn of 1954, with continuance of resulting heavy discharge from the lake well into the winter, and (2) persistence into January of a heavy bloom of blue-green algae, arising from fertilization of the lake. The lake froze over on December 2. By February 7, 1955, the dissolved oxygen content was reduced in much of the volume of the lake to about 60% of saturation. This combination of environmental conditions is advanced as largely determinative of the larger run of the above brook-trout underyearlings into the outlet than experienced in other years, both in respect to numbers and continuance of running into the winter.

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Observations of Fish-Eating Birds and Mammals at Crecy Lake, New Brunswick Over a 12-Year Period

by

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Introduction

Control of fish-eating birds and mammals was exercised at Crecy Lake, Charlotte County, southwestern New Brunswick, as part of a program to improve angling for brook and rainbow trout, *Salvelinus fontinalis* (Mitchill) and *Salmo gairdneri* Richardson (Smith, 1955, 1963). Control was carried out, from March 1952 through October 1963, by a man permanently resident at the lake. Visiting birds and mammals were frightened away from the lake as much as possible. However, those that were not readily frightened away were largely destroyed by shooting or trapping. A majority of the birds flew into the lake in early morning and in the evening. Accordingly, predator control was carried out on the basis of daylight hours rather than a statutory work day.

Migratory, non-game birds and fur-bearing animals out of the trapping season were destroyed under permit from the Wildlife Service, Canada Department of Northern Affairs and National Resources, administering the Migratory Birds Conservation Act, and from the New Brunswick Department of Lands and Mines.

Crecy Lake

Crecy is an unstratified, head-water lake of 50 acres (20 ha), with a mean depth of 7.8 ft (2.4 m). It is tributary to the Bocabec River system, which in turn is tributary to Passamaquoddy Bay. Its geographical position is 67'01"W. long. and 45'14"N. lat. In a straight line, the lake is 4 miles (6.4 km) from the nearest salt water, and about 7 miles (11.3 km) from the open water of Passamaquoddy Bay. Crecy Lake lies at an altitude of 325 ft (99 m) above mean sea level in a heavily wooded area of mixed soft- and hardwood species.

Ice cover, usually from late November and early December until the latter half of April, provided a natural protection to fish from such birds as wintered in the area. Occasionally, in early winter and early spring, when the main body of the lake was frozen over, birds came to a small, open-water area at the lake outlet. Mink and otter were winter visitors.

Crecy Lake was stocked each year with hatchery-reared trout, underyearlings, or yearlings. The consistent stocking may well have attracted more fish predators to the lake than would have otherwise been the case.

Incidence of Fish-Eating Birds and Mammals

Table I gives counts of the species of birds and mammals which were known to have taken trout at Crecy Lake. The counts doubtless include individuals that made more than one visit to the lake, and are thus higher than the actual number of individuals involved. The minimal count is of course given by the number shot or trapped. A list of the common and scientific names of the birds and mammals noted in this paper is given in Appendix I.

None of the birds nested at Crecy Lake or in its immediate environs. A majority of the kingfishers were juveniles and came to the lake in late summer and early autumn. The greatest numbers of kingfishers on the lake often coincided with annual plantings of young trout. Once on the lake, they were not easily frightened off, and they proved particularly troublesome.

Loons, ospreys, and great blue herons were largely summer visitors. The first two species nest within a few miles of Crecy Lake, but we have no knowledge of a heronry in the Passamaquoddy Bay region. The herons frequenting Crecy Lake were probably non-breeding birds.

Red-breasted and American mergansers were most common in autumn. They prey heavily on trout and young salmon in salmonid waters (White, 1957; Elson, 1962), and would doubtless have taken trout at Crecy Lake if they had been left undisturbed. Our records (Table II) with respect to the hooded merganser support Taverner's (1934) statement that this species "probably consumes a smaller proportion of fish than either of its larger relations."

Herring gulls were infrequent visitors, but two killed from a flock of 16 that came to the lake in May 1961 were found to have captured yearling rainbow trout (Table II). Apparently these fish were surface feeding.

Professional trappers are no longer active in the area. Mink, and more particularly otter, have been on the increase in recent years. Otter were especially destructive of brook trout that congregated over a littoral spawning area in November 1951. It is not known how many they ate, but 50 - 60 trout were observed with otter wounds. These fish survived until early winter. However, none with healed scars were taken by anglers in 1952, suggesting no survival of the wounded fish over winter.

Mink often cache some of their catch if prey is plentiful. No caches of trout were found but in October 1960, a mink cache of 73 tadpoles of the bullfrog (*Rana catesbeiana* Shaw) was found near the lake outlet. Peculiarly, this was in the open at the foot of a spruce tree, rather than hidden.

Evidence of Bird Predation

Evidence of predation was gained by examining stomachs of killed specimens (Table II). The objective of the control measures was obviously to prevent predation by birds and mammals. These observations show that the control was

Table I. Total annual sightings and kills of aquatic birds and mammals known to have eaten trout at Crecy Lake. Number killed given in brackets.

	King-fisher	Loon	Osprey	Great blue heron	Red-breasted merganser	American merganser	Hooded merganser	Herring gull	Mink	Otter
1952.....	58(34)	13(1)	25(3)	6(1)	17(4)	10(1)	28(3)	2	14(3)	14(2)
1953.....	62(36)	15(2)	9(1)	7(3)	9(3)	2(1)	22(3)	0	21(8)	19(2)
1954.....	108(68)	16(3)	50(3)	11(4)	26(4)	5(1)	240(22)	0	11(3)	11(1)
1955.....	79(46)	13(4)	5(1)	19(2)	4(4)	0	47(4)	0	8(4)	7
1956.....	60(37)	14(4)	26(1)	7(3)	10(1)	0	15(5)	0	8(3)	15(3)
1957.....	56(34)	20(5)	21(1)	12(2)	6(2)	0	16(5)	0	4(2)	10(2)
1958.....	92(51)	3	4(1)	27(3)	9(2)	0	8(4)	0	6(2)	23(4)
1959.....	55(33)	4(1)	8(2)	27(3)	16(6)	0	19(2)	0	5(1)	3
1960.....	62(42)	6(1)	6(1)	12(3)	16(7)	1	6(1)	0	6(1)	6(1)
1961.....	39(21)	11(2)	17(1)	9(2)	8	0	10(4)	16(3)	3	14
1962.....	45(25)	12(2)	15(1)	8	2	0	3	0	7(1)	5
1963.....	43(23)	13(4)	10	14	4(1)	0	2	0	8	5
Totals:	759(450)	140(29)	196(16)	159(26)	127(34)	18(3)	416(53)	18(3)	101(28)	132(15)

Table II. Record of fish found in stomachs of birds killed at Crecy Lake, 1952-63.

	Number examined	Number eating trout	Number eating killifish[1]	Number eating dace[2]	Number of trout eaten	
					Fingerlings	Yearlings and older
Kingfisher.....	59	17	18	1	15	4
Loon	7	2	0	0	0	9
Osprey.....	1	1	0	0	0	1
Blue heron	6	5	2	0	20	9
Red-breasted merganser...	14	5	10	1	1	11
American merganser...	2	1	1	0	1	0
Hooded merganser...	17	1	4	0	1	0
Herring gull...	2	2	0	0	0	2

[1] *Fundulus diaphanus* (LeSueur)
[2] *Chrosomus eos* Cope and *Rhinichthys atratulus* (Hermann)

imperfect. However, a much improved survival of planted trout to anglers' creels with predator control at Crecy Lake speaks for the effectiveness of the measures (Smith, 1955).

Incidence of Non-Fish-Eating Birds

Table III records sightings of aquatic birds, some of which may have been trout feeders, others not. Besides these, single sightings of the ring-billed gull, pied-bill grebe, surf, and white-winged scoter ducks were made.

Acknowledgments

The writer is indebted to Mr G. Curtis Lowery whose competence as a naturalist, and carefully maintained diaries of the occurrence of fish-eating birds and mammals at Crecy Lake made this account possible.

Table III. Total annual sightings of aquatic birds at Crecy Lake. Not fish eaters or not known to have eaten trout.

	Holboell's grebe	Double-crested cormorant	Canada goose	Ducks					Bonaparte's gull
				Black	Lesser scaup	American golden-eye	Buffle-head	Unknown species	
1952	0	0	0	45	60	9	0	22	0
1953	1	0	0	2	25	9	17	18	0
1954	1	6	0	8	13	0	3	21	0
1955	0	0	0	8	94	22	11	22	0
1956	3	1	0	10	13	3	3	7	2
1957	4	1	0	7	16	86	77	12	1
1958	2	1	0	12	15	62	39	6	1
1959	0	1	0	4	28	51	13	7	0
1960	0	0	0	14	196	12	9	5	0
1961	0	0	8	2	14	42	11	0	0
1962	1	0	0	5	6	14	20	2	0
1963	0	0	23	2	44	4	0	3	0

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Appendix

Table 1

List of birds and mammals

Gavia immer (Brünich)	– Common Loon
Colymbus grisegena holboelli (Reinhardt)	– Holboell's Grebe
Podilymbus podiceps podiceps (Linnaeus)	– Pied-billed Grebe
Phalacrocorax auritus (Lesson)	– Double-crested Cormorant
Ardea herodias Linnaeus	– Great Blue Heron
Branta canadensis Linnaeus	– Canada Goose
Anas rubripes tristis Brewster	– Common Black Duck
Nyroca affinis (Eyton)	– Lesser Scaup Duck
Glaucionetta clangula americana (Bonaparte)	– American Golden-eye
Charitonetta albeola Linnaeus	– Buffle-head
Melanitta deglandi (Bonaparte)	– White-winged Scoter
Melanitta perspicillata (Linnaeus)	– Surf Scoter
Oidemia americana Swainson	– American Scoter
Lophodytes cucullatus (Linnaeus)	– Hooded Merganser
Mergus merganser americanus Cassin	– American Merganser
Mergus serrator Linnaeus	– Red-breasted Merganser
Pandion haliaetus carolinensis (Gmelin)	– Osprey
Larus argentatus Coues	– Herring Gull
Larus delawarensis Ord	– Ring-billed Gull
Larus philadelphia (Ord)	– Bonaparte's Gull
Megaceryle alcyon alcyon (Linnaeus)	– Eastern Belted Kingfisher
Lutreola vison vison Schreber	– Mink
Lutra canadensis canadensis (Schreber)	– Otter